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Evaluation of Hydrochemical Attributes of the Amachara Mining Area, Lower Benue Trough

Obasi, P. N.[‡], Obini, N. Ani, C. C., Okolo, C. M

[‡]Department of Geology, Ebonyi State University, P.M.B., 053, Abakaliki, Nigeria

Email address: obasiphilip26@gmail.com

***Abstract*— *Hydrochemical evaluation of Amachara and its environs was carried out. The area lies between lat. 6º 30'N and 6º 35'N, and long. 8º05'E and 8º10'E. The area is underlain by the Abakaliki Shales of the Asu River Group (Albian). Twenty –seven (27) parameters (4 physical and 23 chemical) were analyzed for ten water samples collected from different groundwater and surface water sources across the area. Atomic Absorbtion Spectrophotometer (AAS), AA240 series was used to analyze the ions concentrations. The result reveal that chemical constituents such as As, $S0_4^{2-}$, Pb^{2+}, Se^{2+}, Hg^{2+}, and Cd^{2+} occurs at values above the maximum permissible limits, thereby causing significant contaminations. The most prevalent ionic concentration includes Cl^-, $S0_4^{2-}$, Na^{2+}, Ca^{2+}, Se^{2+}, Mg^{2+}, K^+, As, Cd^{2+}, Hg^{2+}, Co^{2+}, Ni^{2+}, Zn^{2+} and Cu^{2+}. The sources of these high concentrations of chemical elements in the water resources of the study area is attributed to the dissolution of minerals from the abandoned lead-zinc mine and also from agricultural practices as well as sewage effluents.*

***Keywords*— *Hydrochemical, mining, lead- zinc and contaminant*.

I. INTRODUCTION

Water as a natural resource is fundamental to life. It is vital in maintaining the metabolic processes of life and makes up about 60% of body weight in human being (Fasunwon and others, 2010). Among the various sources of water, groundwater is known to be more appropriate and often meets the criteria of water quality, and most widely used as sources of water in most African countries, Nigeria inclusive. Groundwater has unique features, which render it suitable for public water supply (Alexander, 2008; Offodile, 1983). It has excellent natural quality, usually free from pathogens, colour, and turbidity and can be consumed directly without treatment (Jain and others, 1996). Its widely distributed and can frequently develop incrementally at points near the water demand, thus avoiding the need for large-scale storage, treatment and distribution system (Alexander, 2008). Groundwater is particularly important as it accounts for about 88% of safe drinking water in rural areas, where population is widely dispersed and the infrastructure needed for treatment and transportation of surface water does not exist. The chemistry of groundwater is the resultant of all the processes and reactions that act on the water from the time it condensed in the atmosphere to the time it is discharged by well in spring and varies from place to place and with the depth of the water table (Todd, 1980). The Amachara area, is endowed with galena and other sulphide ore deposits which has led to the mining and inappropriate dumping of mining wastes in the area. These mining activities have led to the excavation and abandoning of mining pits in many places in Ebonyi State, including Ameka, Enyigba, Mkpuma Akpatakpa, Mpuma Ekwuoku and the study area. Many researches including Nnabo and others (2011), Eze and Anike (2009),Obiora and others (2015), Obasi and Akudinobi (2015), Obasi and others (2015), have shown that these abandoned mines have effect on the water and soils/ sediments of these areas. Obasi and others 2015, also observed that anthropogenic and geogenic effect increase the rate at which these mineral deposits weather and release elements into the soil. Moreso, precipitation and infiltration leach the elemental constituents from the soil zone into the groundwater regime through the structural pathways in the sediments. The plume disperses within the groundwater environment and introduces some hydrogeochemical reactions between the groundwater and the host rock. The geochemical processes occurring within the groundwater and reaction with the aquifer minerals have profound effect on water quality (Prasanna, 2011).

Amachara is a rural community in Izzi Local Government Area of Ebonyi State, Southeastern Nigeria. Regionally, the area is situated within the southern extension of the Benue Trough (Fig 1) between latitude 6°30' N and 6°35'N and longitude 8° 05' E and 8°10' E. Ebonyi River and its tributaries such as Ogbogbo River, Egwudinagu River, Onyirigbo River and Awunimi River provide aqueous media for the transportation of the hydrochemical attributes from one point to another. These tributaries are perennial and usually overflow their banks at the peak of the rainy season.

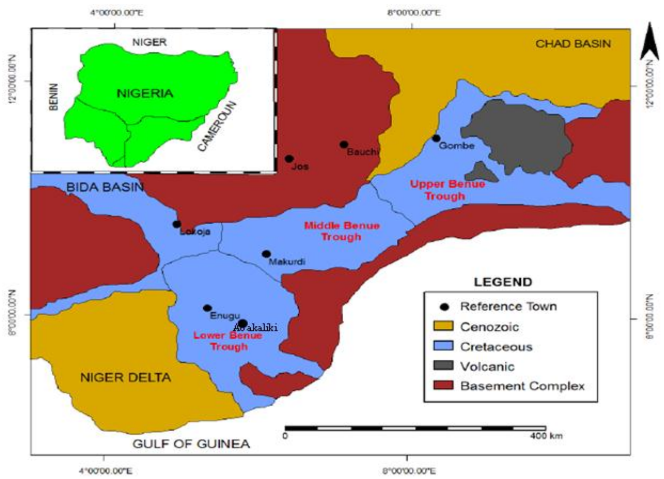

Fig. 1. Regional geologic map of the Benue Trough, relative to other basins (after Zarborski, 1988).

It is therefore important that the quality of the water resources of Amachara and its environs where lead-zinc (Pb-

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Zn) mineralization are commonly present be evaluated for the major hydrochemical attributes. Also, Obasi and others, (2015), has shown that these ponds serve as sources of water for domestic uses for the villagers. Although, the mining of the lead-zinc has been abandoned, the devastative effects on the groundwater may have continued to linger (Okogbue and Ukpai, 2013). Water quality is of enormous concern in the study area. This study is aimed at determining the chemical attributes and their concentrations in the water resources in the area and at the same time sets to compare the qualities with World Health Organization (WHO) standards for effective evaluation of the resources as such evaluation will assist in water resource management.

II. GEOLOGICAL SETTING

Amachara and its environs lies within the southeastern part of southern Benue Trough (fig 1). The origin of the trough has been associated with the break-up of the Gondwanaland in the early Cretaceous (Wright, 1979). The area is underlain by the Asu-River Group sediments. The Asu River Group was deposited by the first marine transgression in the trough, which started in the mid-Albian period. It is predominately shales and localised development of fine-grained sandstone, siltstone and limestone (Reyment, 1965). The basin is also characterized by the Santonian tectonism which resulted to major folding, faulting, fracturing, volcanic intrusion and Pb-Zn mineralizations. Hydrogeologically, the Abakaliki shale form an aquiclude, which is a problem to groundwater occurrences, but it is aquiferous where the shale is densely weathered and fractured. This can be linked to the Santonian tectonism, which affected the area (Kogbe, 1987).

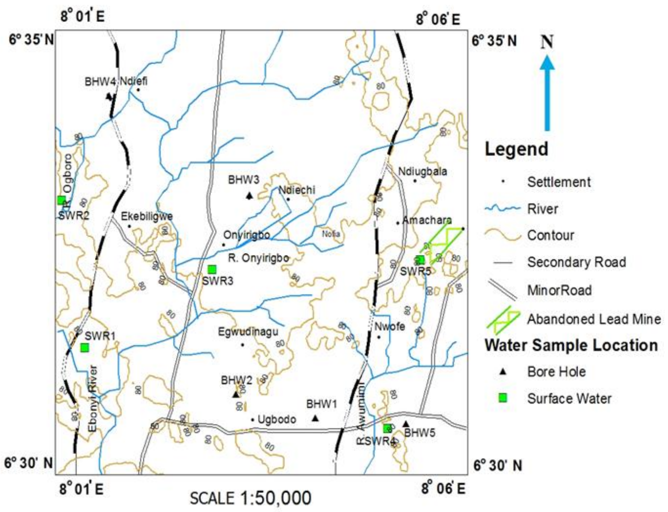

Fig. 2. Map showing the sample collection points.

III. METHODOLOGY

Ten (10) water samples were collected (fig. 2) from different location spread across the study area from hand pump wells, surface waters\mine pit (which in most cases are sources of drinking water for the community). The boreholes were pumped continuously for five (5) minutes before samples were taken aseptically for analysis according to Cheeseborough, (1991), and Ogbonna and others, (2007). Twenty-seven (27) parameters were analyzed for in each of the ten (10) samples. The analytical procedures were according to the American Public Health Association (APHA, 1998). Electrical conductivity and pH of the water samples were measured by Electrometric method, using laboratory pH meter and conductivity cell according to American Public Health Association (APHA) 2510B guideline Model DDS-307(APHA;1998). The Analysis of cations and anions in the samples were carried out employing the fast sequential standard procedures recommended by American Public Health Association (1998). The heavy metal analysis was done using the Atomic Absorption Spectrophotometer (AAS), AA240 series model according to APHA, 1995 guidelines.

IV. RESULTS AND DISCUSSION

A. Physical Parameters

The water samples analysed have a pH range of 2.78 – 6.68. This result shows that some of the samples are acidic, especially sample SWR5 (the mine pond) and SWR4 (Awumini River), where the pond water flows into others are comparatively low and within the WHO (2011) limit of 6.5 – 8.5. The turbidity of all the water samples analysed ranges from 30.00 – 940 NTU (fig. 3). These falls above the WHO limit of 5. The high turbidity of the water is due to the suspension of dissolved particulate matters such as clay or silt. These water samples with high turbidity presents colloidal materials which provide absorption sites for chemicals that may be harmful or cause undesirable taste and odours.

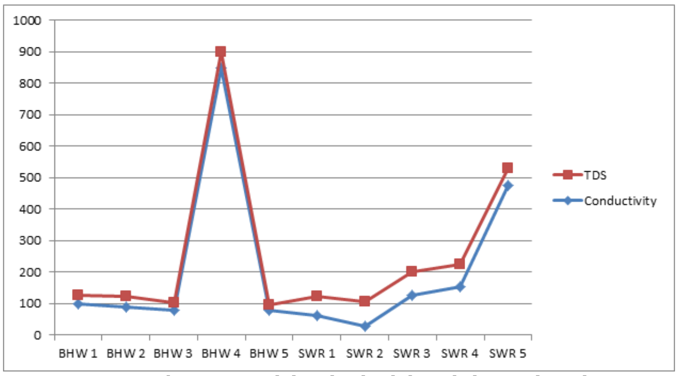

Fig. 3. Variation between total dissolved solids and electrical conductivity.

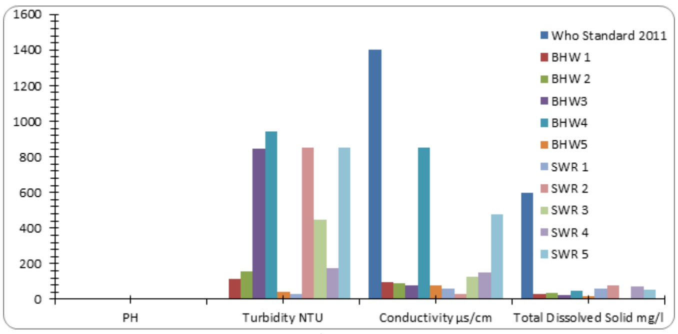

Fig. 4. A bar chart representation of the physical parameters in the samples.

The implication of this in the study area is that high turbidity indicates the presence of disease causing organisms such as bacteria, viruses and parasites that can cause diseases such as nausea, diarrhea, cramps coupled with headache

(USEPA, 2004). The electrical conductivity of water leads to the total concentration of dissolved ions in water. Hundred percent of the samples measured conductivities below the WHO (2011) limit of 1000µs/cm. The conductivity ranged from 29.00 - 850µs/cm, with highest conductivity of 850µs/cm recorded for BHW 4 Amachara Primary School (fig 4). The total dissolved solids (TDS) ranges from 17.4 – 78.40 mg/l with highest value of 78.40 mg/l recorded for SWR 2 Ogbogbo River. The total dissolved solids (TDS) measured in the samples were below WHO (2011) limit of 500 mg/l. Many dissolved substances are undesirable in water. Dissolved minerals, gases and organic constituents may produced aesthetically displeasing colour, taste and odour . Some dissolve organic chemicals may deplete the dissolved oxygen in the receiving waters. Fig 3 shows a direct variation between total dissolved solids (TDS) and conductivity for the samples analysed.

B. Chemical Parameters

The result show that cations including Calciums (Ca^{2+}), Magnesium (Mg^{2+}), Sodium(Na^{+}), Potassium (K^{+}) and Iron (Fe^{2+}) has concentrations ranging from 0.00 mg/L – 45.02 mg/L, 0.00 mg/L – 20.44 mg/L, 3.42 mg/L – 114 .91 mg/L, 1.26 mg/L – 6.94 mg/L and 0.00 mg/L – 17.14 mg/L respectively (fig 5). The concentration of Calcium is within the permissible limit of 75 mg/L for drinking water. Although, high concentrations were observed around Ugbodo, Egwudinagu and Ndiechi. This can be attributed to the dark grey shales which underlie the area. Magnesium, Sodium and Potassium shows moderate concentration and are below the permissible limit for all samples. Their presence in the water resources in the area can emanate from the weathering of Silicate minerals which make up the intrusive rocks which underlies the area. The concentration of Iron in some of the samples analyzed is excessively high. Sample SWR2 (Ogbogbo River), SWR3 (Onyirigbo River) and SWR5 (Ekwegburu mine) shows very high concentration 0.83 mg/L, 0.346 mg/L and 17.149 mg/L respectively. This results shows that surface water resources around the mine sites have high concentration of Iron.

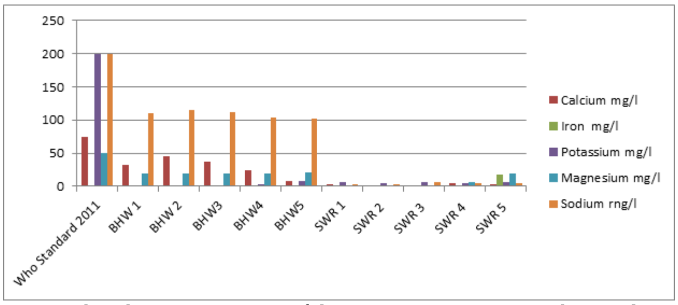

Fig. 5. A bar chart representation of the cation concentrations in the samples.

TABLE I. Summary of hydrogeochemical analysis compared with Standard.

PARAMETERS	Who Standard 2011	BHW 1 Ugbodo	BHW 2 Egwudinagu	BHW3 Ndiechi	BHW4 Amachara School	BHW5 St. Thomas Nwofe	SWR 1 Ebonyi River	SWR 2 Ogbogbo River	SWR 3 Onyirigbo River	SWR 4 Awumini River	SWR 5 Mine Pit
PH	6.5-8.5	6.61	6.68	4.78	5.75	4.87	6.500	6.510	6.040	3.540	2.870
Chloride mg/l	250	52	37	39	2360	47	34.000	165.000	28.000	30.000	2500.000
Turbidity NTU	5	115	157	844	940	041	30.000	849.000	448.000	175.000	854.000
Conductivity µs/cm	1000	98.5	88.3	79.8	850	78.2	61.000	29.000	126.000	152.000	475.000
Nitrate mg/l	50	2.436	4.108	1.892	3.464	1.782	0.190	0.431	0.286	1.072	0.981
Total Dissolved Solid mg/l	500	28.4	34.2	21.6	50	17.4	62.100	78.400	73.6.00	71.580	54.700
Phosphate mg/l	10	10.442	11.112	12.671	10.662	11.784	100.943	69.811	103.835	400.529	141.514
Sulphate mg/l	250	329.085	292.165	333.315	510.26	238.67	45.000	56.000	68.000	54.000	93.000
Arsenic mg/l	0.01	1.610	3.580	2.734	2.858	2.936	0.010	0.011	0.000	0.000	0.000
Aluminium mg/l	0.2	0.00	0.00	0.00	0.00	0.00	0.000	0.001	0.000	0.000	0.900
Calcium mg/l	75	32.951	45.028	37.244	24.380	8.579	2.440	0.000	0.000	4.92	3.110
Selenium mg/l	0.04	20.00	21.391	26.608	26.782	24.869	0.005	0.002	0.000	0.000	0.000
Copper mg/l	2	0.028	0.00	0.00	0.008	0.022	0.341	0.000	0.043	0.000	0.030
Lead mg/l	0.01	2.727	2.770	2.263	2.430	2.758	1.150	0.000	0.080	0.037	6.140
Iron mg/l	0.3	0.00	0.00	0.00	0.00	0.00	0.135	0.831	0.346	0.000	17.149
Potassium mg/l	200	1.505	1.260	1.378	2.436	8.542	6.233	4.996	5.658	4.902	6.942
Chromium mg/l	0.05	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.911
Magnesium mg/l	50	19.604	19.563	19.527	19.338	20.449	0.980	0.000	0.000	6.40	18.849
Zinc mg/l	3	0.00	0.036	0.00	0.00	0.00	0.004	0.000	0.093	0.000	0.011
Nickel mg/l	0.03	0.00	0.00	0.091	0.084	0.058	0.022	0.021	0.000	0.000	0.000
Manganese mg/l	0.4	0.00	0.00	0.00	0.00	0.00	0.067	0.000	0.081	0.029	0.011
Cadmium mg/l	0.003	0.374	0.264	0.278	0.433	0.447	0.005	0.000	0.034	0.000	0.014
Sodium rng/l	200	110.62	114.91	111.93	103.38	101.74	3.560	3.420	5.751	5.326	5.000
Cobalt mg/l	0.003	0.168	0.00	0.206	0.236	0.056	0.042	0.000	0.000	0.006	0.000
Mercury mg/l	0.006	0.372	0.223	0.372	0.363	0.249	0.000	0.000	0.200	0.000	2.300
Silver mg/l	0.1	0.00	0.00	0.00	0.00	0.00	0.053	0.025	0.035	0.039	0.028
Molybdenum mg/l	0.07	0.00	0.00	0.00	0.00	0.00	0.001	0.008	0.000	0.000	0.000

This can be attributed to the weathering of Iron-rich minerals and dissolution of gangues and mine dumps which are carried by run-off into the surface water bodies. Anions including sulphate ($S0_4^{2-}$), Nitrate ($N0_3^-$) Chloride (Cl^-) and phosphate

(PO_4^{2-}) showed values ranging from 45.00 mg/L – 510.26 mg/L, 0.28 mg/L – 4.10 mg/L, 28.00 mg/L – 2360 mg/L and 10.44 mg/L – 400.52 mg/L respectively. Nitrate was observed to fall within the permissible limit of 50 mg/L for water quality criterion according to WHO, 2011 standard. Its very low concentration in the area indicates its origin from non-point sources, probably sewages, leachates from dumpsites and agricultural practices involving the applications of pesticides.

Nitrate is a natural constituent of water but its excessive concentration have the potential to harm infant human beings and livestock (Freeze and Cherry, 1979). Chloride occurs naturally in water from minerals and salts. Its concentration in the water resources in the area falls within the permissible limit of WHO, 2011 except for samples BHW4 (Amachara primary school) 2360 mg/L and SWR5 (St. Thomas Nwofe) 2500 mg/L. The concentration in these samples may be due to the leaching of sewage effluents and high dissolution of chloride ions into the water resources of the area from the abandoned mine. Chloride in the water originates from both natural and anthropogenic sources like runoff containing inorganic fertilizers, animal feeds, irrigation drainage and seawater intrusion in coastal area (O'Brien and Majewski, 2002; Aghazadeh and others 2011) . According to Todd, 1980, excess Cl^- of 100 mg/L impact a salty taste in water and also causes serious health damage. Sulphate ion occurs at very high values in some of the samples. This include BHW1 (Ugbodo), BHW2 (Egwudinagu), BHW3 (Ndiechi) and BHW4 (Amachara primary school) of 329.085 mg/L, 292.162 mg/L l, 333.315 mg/L, and 510.26 mg/L respectively. This high concentration of So_4^{2-} can be linked to the weathering of the chalcopyrite ores which underlay the area. Minerals dumps and gangues also deteriorate and finds their ways through run-offs into water bodies (Obasi *et al.*, 2015). Phosphate ions were observed to fall slightly above the WHO,2011 Water quality standard with a drastic high values in SWR4 Awumini River (400.5 mg/L) , SWR5 Mine Pit (141.5 mg/L), SWR1 Ebonyi River (100.9 mg/L), SWR3 Onyirigbo River (103.8 mg/L) and SWR2 Ogbogbo River (69.8 mg/L). The sources of this high concentrations of phosphate ions in the water resources can be attributed to the high oxidation sulphide ores from the mine as well as agricultural fertilizers.

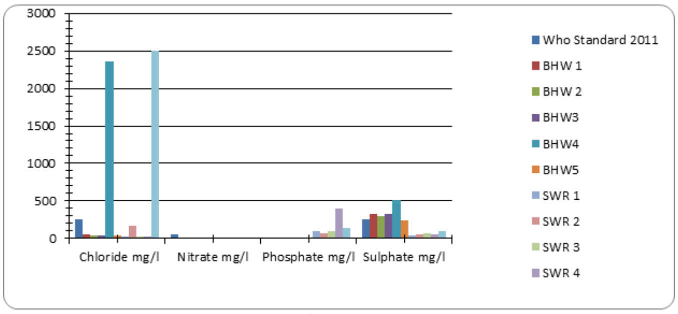

Fig. 6. A bar chart representation of the Anions concentrations in the samples.

C. Heavy Metals

Heavy metallic ions such as Arsenic (As), Lead (Pb^{2+}), Zinc (Zn^{2+}), Cadmium (Cd^{2+}), Selenium (Se^{2+}) and Mercury (Hg^{2+}) values ranges from 0.00 mg/L – 3.58 mg/L, 0.00 mg/L – 6.14 mg/L, 0.00 mg/L – 0.09 mg/L , 0.00 mg/L – 0.44 mg/L, 0.00 mg/L - 26.78 mg/L and 0.00 mg/L – 2.30 mg/L respectively. The concentrations of arsenic in the samples was observed to fall above the permissible limits of 0.01 mg/l for BHW1 Ugbodo (1.6 mg/L), BHW2 Egwudinagu (3.5 mg/L), BHW3 Ndiechi (2.7 mg/L), BHW4 Amachara primary school (2.8 mg/L) and BHW5 St. Thomas Nwofe (2.9 mg/L) fig.7. However, its presence is attributed to the dissolution of sulphide from the mine. Lead (Pb^{2+}) occurs at values exceeding the permissible limit of 0.01 mg/L for BHW1 Ugbodo, BHW2 Egwudinagu, BHW3 Ndiechi, BHW4 BHW5 St. Thomas Nwofe, SWR1 Ebonyi River, SWR2 Ogbogbo River, SWR3 Onyirigbo River and with an appreciably high value of 6.14 mg/L in SWR5 (abandoned mine). Its significant concentration in the water is as a result of the high dissolution of lead ions into the water regime from the abandoned lead – zinc mines. Mercury (Hg^{2+}) values ranges from 0.00 – 0.37 mg/L. Its concentration varies within the area, however, samples, BHW1 Ugbodo, BHW2 Egwudinagu, BHW3 Ndiechi, BHW4 Amachara primary school, BHW5 St. Thomas Nwofe, SWR3 Onyirigbo River and SWR5 Mine pit with values exceeding the permissible limits with only SWR1 Ebonyi River, SWR2 Ogbogbo River and SWR4 Awumini River falling within the limits. This high concentration is related to the dissolution of mercury from the abandoned mine into the water system. Natural waters, usually contains very low levels of zinc less than 0.1 mg/l (ADWD, 1998). Although, the concentrations of zinc in some of the analysis results shows zero values (BHW1 Ugbodo, BHW3 Egwudinagu, BHW4 Amachara primary school, BHW5 St. Thomas Nwofe, SWR1 Ebonyi River, SWR2 Ogbogbo River and SWR4 Awumini River) , however, its occurrences in BHW 2 Egwudinagu, SWR1 Ebonyi River, SWR3 Onyirigbo River and SWR5 Mine pit with the respective values 0.03 mg/L, 0.004 mg/L, 0.09 mg/L and 0.01 mg/L still falls within the WHO,2011 permissible limit for water quality. Selenium concentration in the water samples falls below the permissible limits for water quality SWR1 Ebonyi River (0.005 mg/L), SWR2 Ogbogbo River (0.002 mg/L), SWR3 Onyirigbo River (0.000 mg/L), SWR4 Awumini River (0.000 mg/L) and SWR5 Mine pit (0.000 mg/L) but showed profound high values in BHW1 Ugbodo (20.00 mg/L), BHW2 Egwudinagu (21.39 mg/L), BHW3 Ndiechi (26.60 mg/L), BHW4 Amachara primary school (26.78 mg/L) and BHW5 (24.86 mg/L) above the permissible limits. This high concentration may be attributed to the dissolution of selenium from the Pb – Zn mine into the water system. Cadmium ion concentration within the area falls above the permissible limits for all the samples except for SWR2 Ogbogbo River and SWR4 Awumini River which show zero values. Generally, dangerous effects (lead poisoning, stunted growth, fingernails loss, intestine, kidney and liver problems and disorderliness of the central nervous system) posed by this heavy metals to the human body upon consumption of unhygienic or untreated water, takes a long period of time before manifestation. However, adequate treatment measures should be carried out on the water before consumption. Other heavy metals including Manganese (Mn^{2+}), Copper (Cu^{2+}),Nickel (Ni) Silver (Ag^+), Chromium (Cr^{3+}), Aluminum (Al^{2+}), Cobalt (Co)

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and Molybdenum (Mo^{+}) with respective values that varies from 0.00 mg/L – 0.08 mg/L, 0.00 mg/L – 0.34 mg/L, 0.00 mg/L – 0.09 mg/L, 0.00 mg/L – 0.05 mg/L, 0.00 mg/L – 0.91 mg/L, 0.00 mg/L – 0.90 mg/L, 0.00 mg/L – 0.23 mg/L and 0.00 mg/L – 0.008 mg/L were also analysed. Manganese, Copper, Chromium, Silver, Aluminium, Nickel, Molybdenum, Cobalt occur within the WHO permissible limits in all the water samples except, for sample SWR5 (the mine pit). This is due to high chemical activities taking place in the mine. Samples BHW2 Egwudinagu, BHW3 Ndiechi, SWR2 Ogbogbo River and SWR4 Awumini River show complete absence of copper. Copper causes stomach and intestinal distress, liver and kidney damage. Chromium concentration value falls within the permissible limit of 0.03 mg/L but shows significant increase in concentration exceeding the permissible limit in sample (SWR5). This high concentration of SWR5 Mine pit, is due to dissolution of chromium ions from the metallic ore deposit into the water bodies.

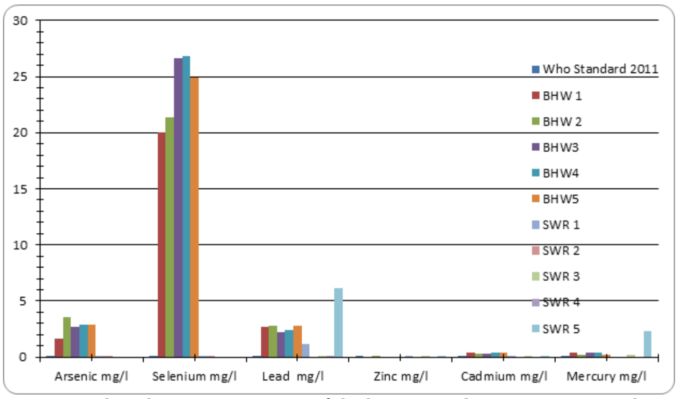

Fig. 7. A bar chart representation of the heavy metal concentrations in the samples.

It therefore follows that adequate treatment of water should be carried out for wells and streams around the mine pit (SWR5). Silver ion concentration varies significantly but falls within the permissible limit of 0.1 mg/L due to non-dissolution of silver ions into the water resources from the mine site. Aluminum (Al^{2+}) shows zero concentrations in BHW1 Ugbodo, BHW2 Egwudinagu, BHW3 Ndiechi, BHW4 Amachara primary school, BHW5 St. Thomas Nwofe, SWR1 Ebonyi River, SWR3 Onyirigbo River and SWR4 Awumini River but with a significant high value of 0.9 mg/L in SWR5 Mine pit above the permissible limit of 0.2 mg/L. This can emanate from the weathering of intrusive rocks in the area. Nickel ion occurrence in the samples falls below the WHO, 2011, permissible limit with the highest concentration in BHW3 Ndiechi. Cobalt ion concentration in most of the samples (BHW1 Ugbodo, BHW3 Ndiechi, BHW4 Amachara primary school, BHW5 St. Thomas Nwofe and SWR1 Ebonyi River) falls within the permissible limit of 0.03 mg/L with only samples BHW2 Egwudinagu, SWR2 Ogbogbo River, SWR3 Onyirigbo River, SWR4 Awumini River and SWR5 Mine pit falling above permissible limit. Molybdenum ion concentration ranged from 0.00 – 0.008 mg/L, although majority of the sample result shows a uniform values falling within the permissible limit of 0.07 mg/L with a slight deviation in uniformity recorded for SWR2 Ogbogbo River and SWR1 Ebonyi River.

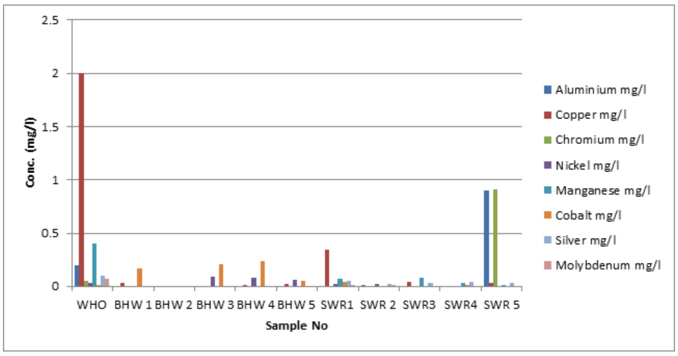

Fig. 8. A bar chart representation of the trace element concentrations in the samples.

V. SUMMARY, CONCLUSION AND RECOMMENDATIONS

A. *Summary and Conclusion*

Amachara and its environs is underlain by poor groundwater yielding aquiclude (the Abakaliki Shale of the Asu River Group) but produces prolific aquifers where the shale is weathered and fractured. Analyses of the water samples showed that much of the water is of good quality and having met the World Health Organization (WHO, 2011) recommendation value. However, some of the ions (both cations, anions and heavy metals) such as As, So, Pb, Se, Cd and Hg were above the WHO recommendations for a safe drinking water. But the most prevalent ionic concentration includes Cl^{-}, So^{2-}, Na^{+}, Ca^{2+}, Se^{2+}, Mg^{2+}, K^{+}, As^{3+}, Cd^{2+}, Hg^{+}, Cot, Ni^{+}, Zn^{2+} and Cu^{2+}. The pH of the samples indicates fairly- strongly acidic as the pH ranged from 4.78-6.68 (BHW) and 2.87-6.51(SWR) and also fresh with a total dissolved solids of less than 1000 mg/l respectively. The extremely high levels of turbidity could be attributed to the presence of decaying organic matters. From this study, it can be seen that the analysis revealed the water resources quality from Amachara and its environs to have almost the same qualities except for few locations closed to the mine, which are not safe for drinking and domestic purposes. Thus, as water seeps through the ground and adds to its mineral content, much of its constituents are filtered out. Thus, a deep well is likely to produce water that is free from contaminants. It is pertinent to conclude here, by saying that it´s apparent that the composition/lithology of the study area has no matter how little - influence on the water quality.

B. *Recommendations*

The hydrogeochemical analysis result shows that some of the chemical constituents in the water sources of the area are in high concentration above the permissible values for domestic water supply. Some of these water sources are close to the abandoned lead-zinc mine at Ekwuburu (BHW 4) and the water can be said to be clear/safe for domestic use by mere looking, therefore deep boreholes are advisable to be sunk as source of good drinking water in the area. There should be a serious advises and awareness for the inhabitants of this area on the dangers of this high ionic concentrations in the water sources. The government should start a campaign against the use of this water for domestic purposes and also provide alternative source of drinking water to the area.

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